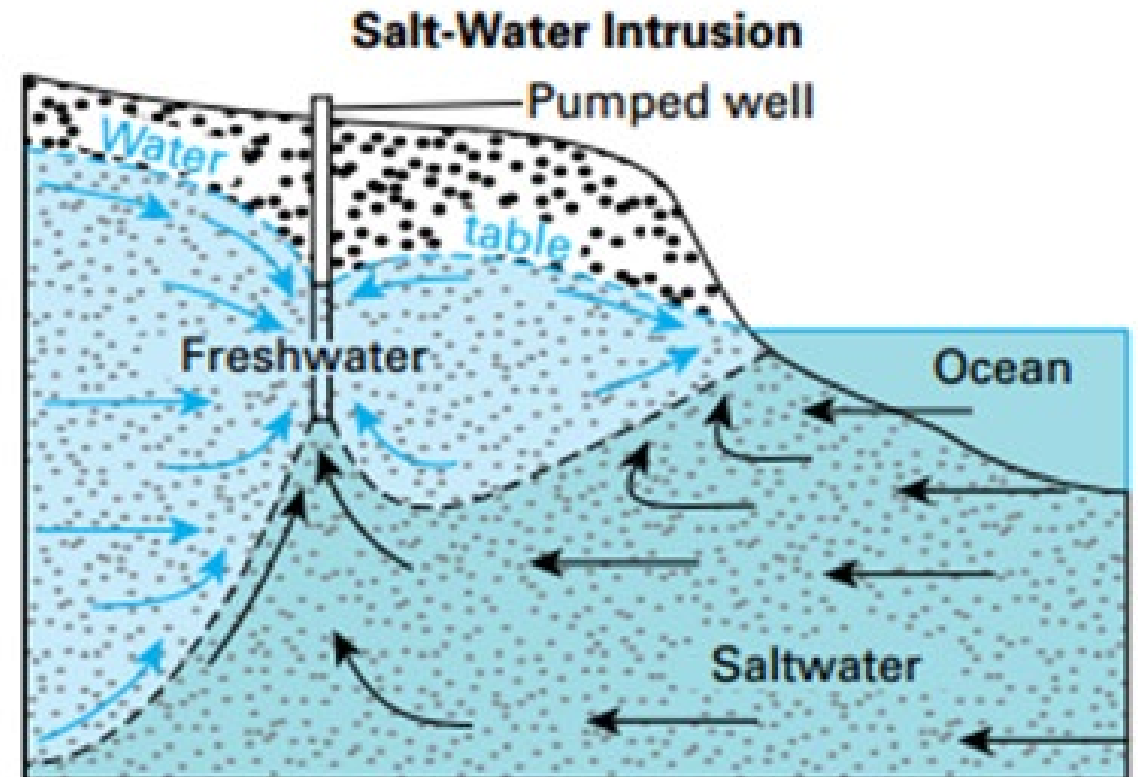
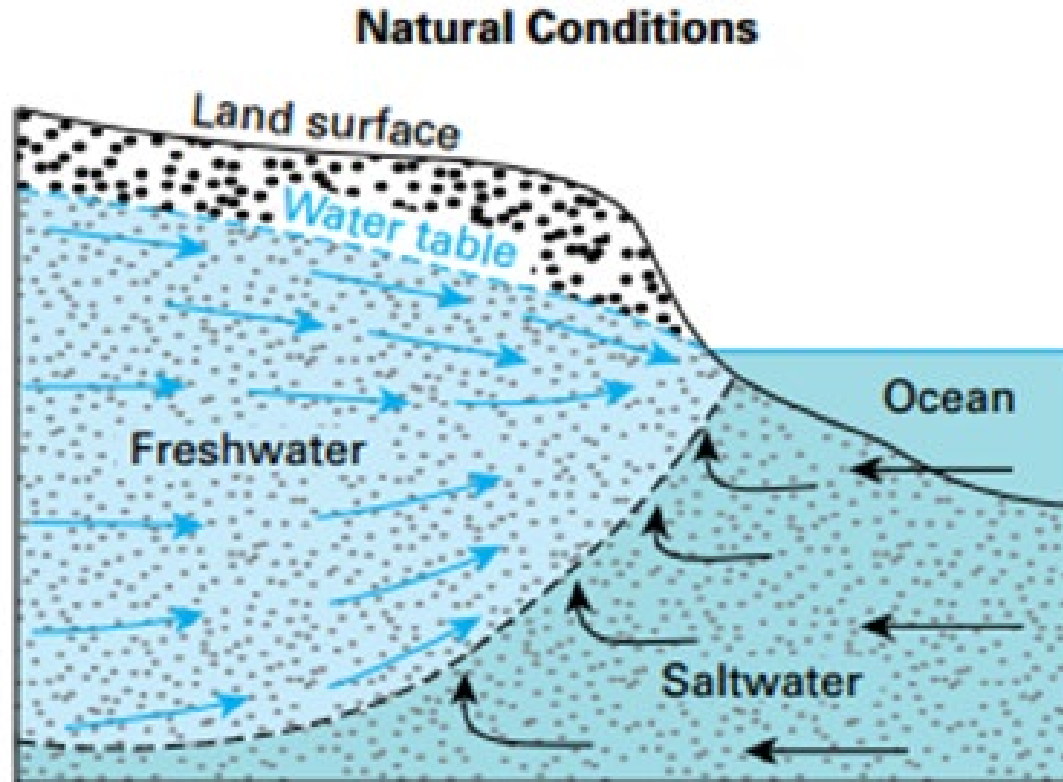




Newfoundland and Labrador Saltwater Intrusion Vulnerability Study

Ryan Threndyle – Hydrogeologist
Colin Walker – Sr. Hydrogeologist

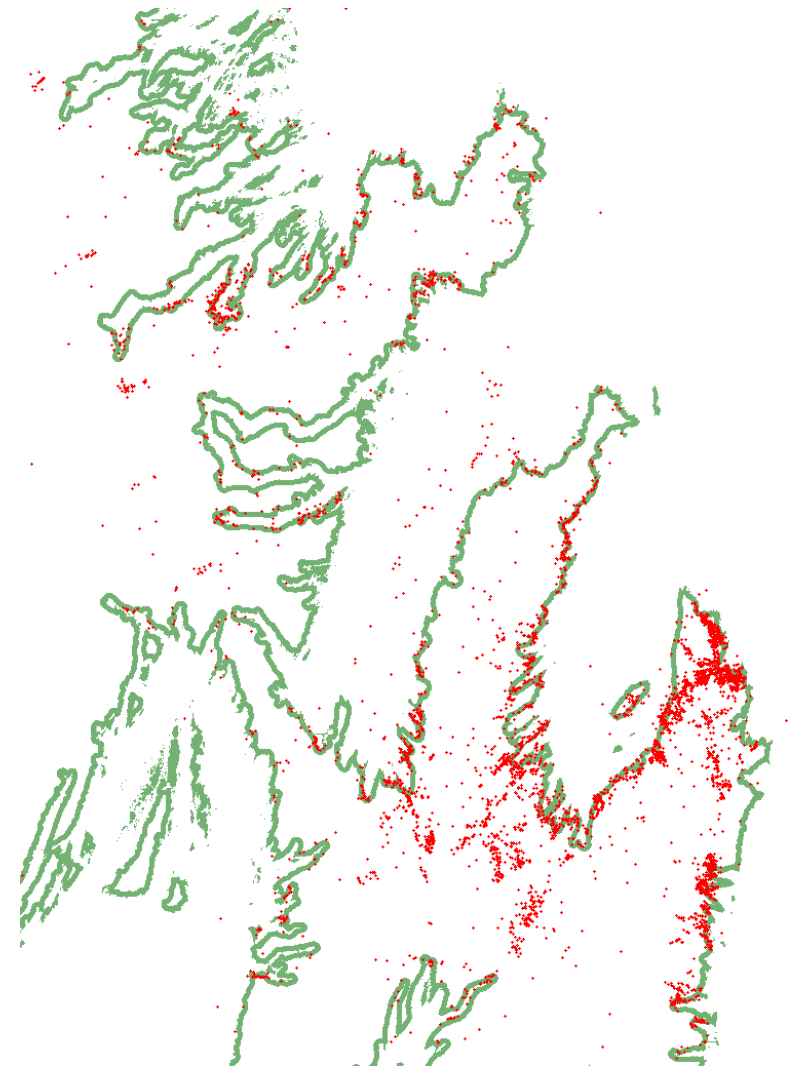
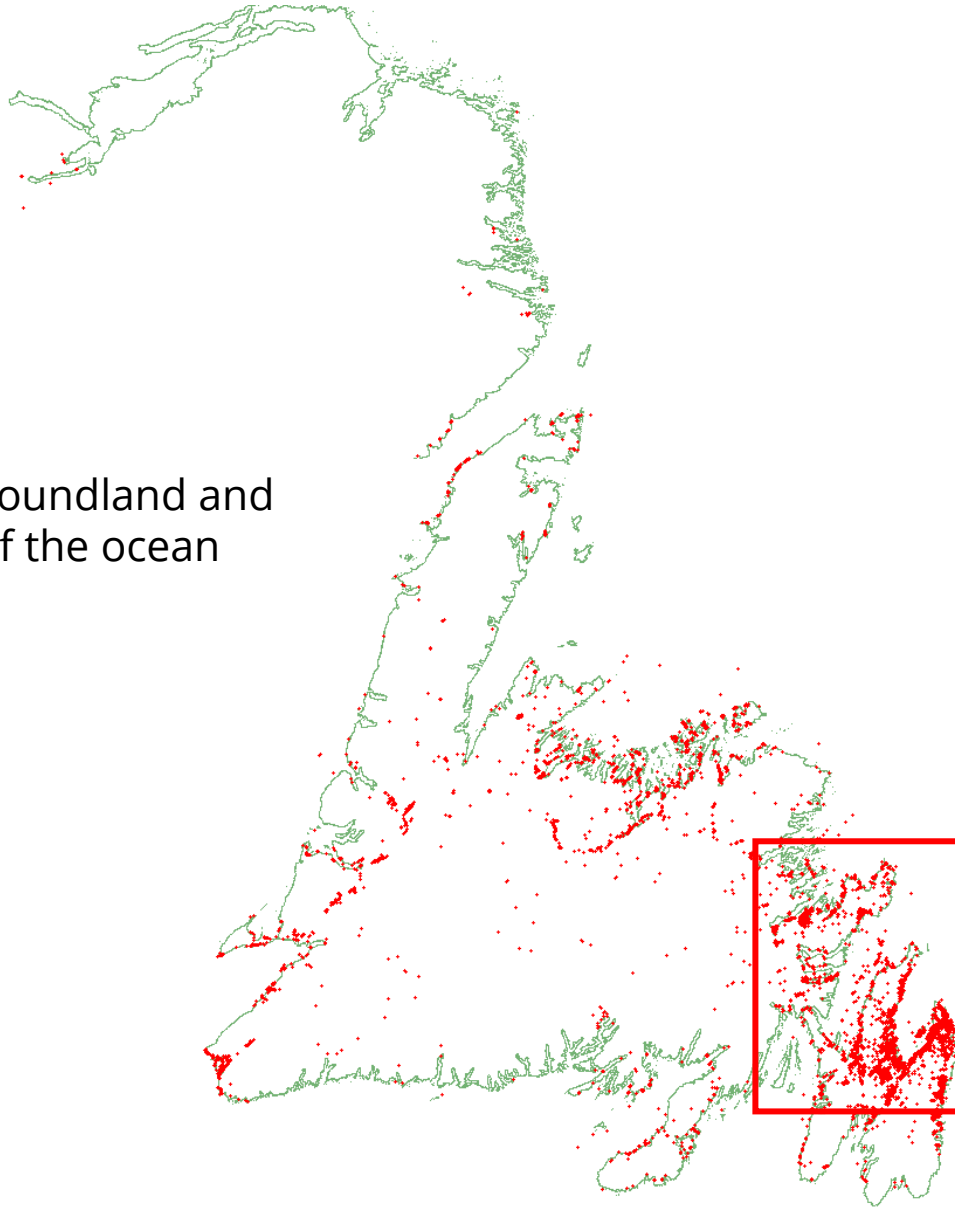
What is Saltwater Intrusion (SWI)?



Wells in Newfoundland and Labrador

> 50%

of the drilled wells in Newfoundland and Labrador are within 1Km of the ocean





What is the best way to assess the risk of SWI at the provincial scale?

Summarize the important parameters that influence SWI

$$z^2 = \frac{2qx\rho_f}{K(\rho_s - \rho_f)} + \left[\frac{q\rho_f}{K(\rho_s - \rho_f)} \right]^2$$

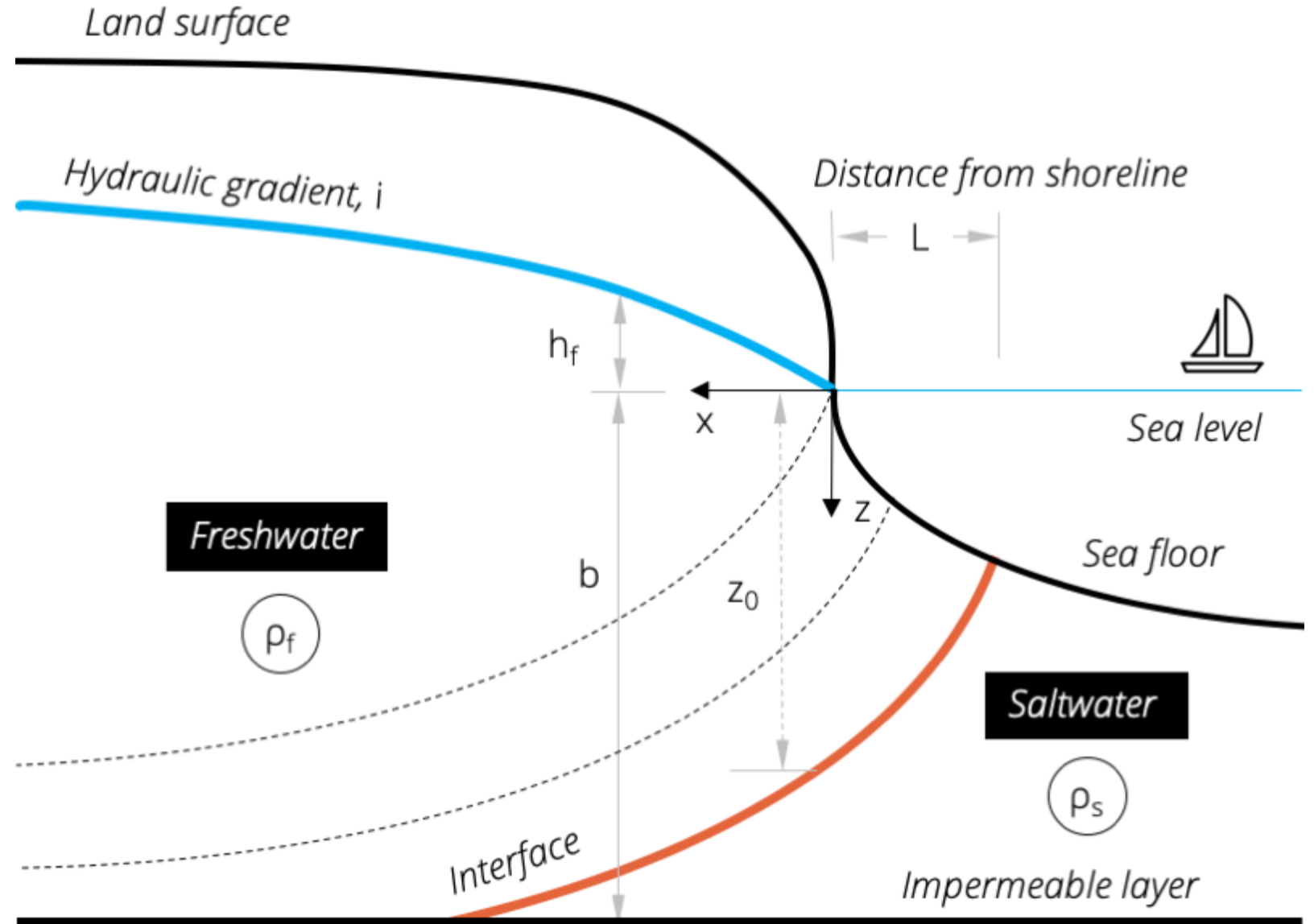
Distance from shoreline

Freshwater flux (Gradient)

- Elevation
- Slope

Hydraulic conductivity

- Geology



Quantities that affect SWI

Distance from shoreline

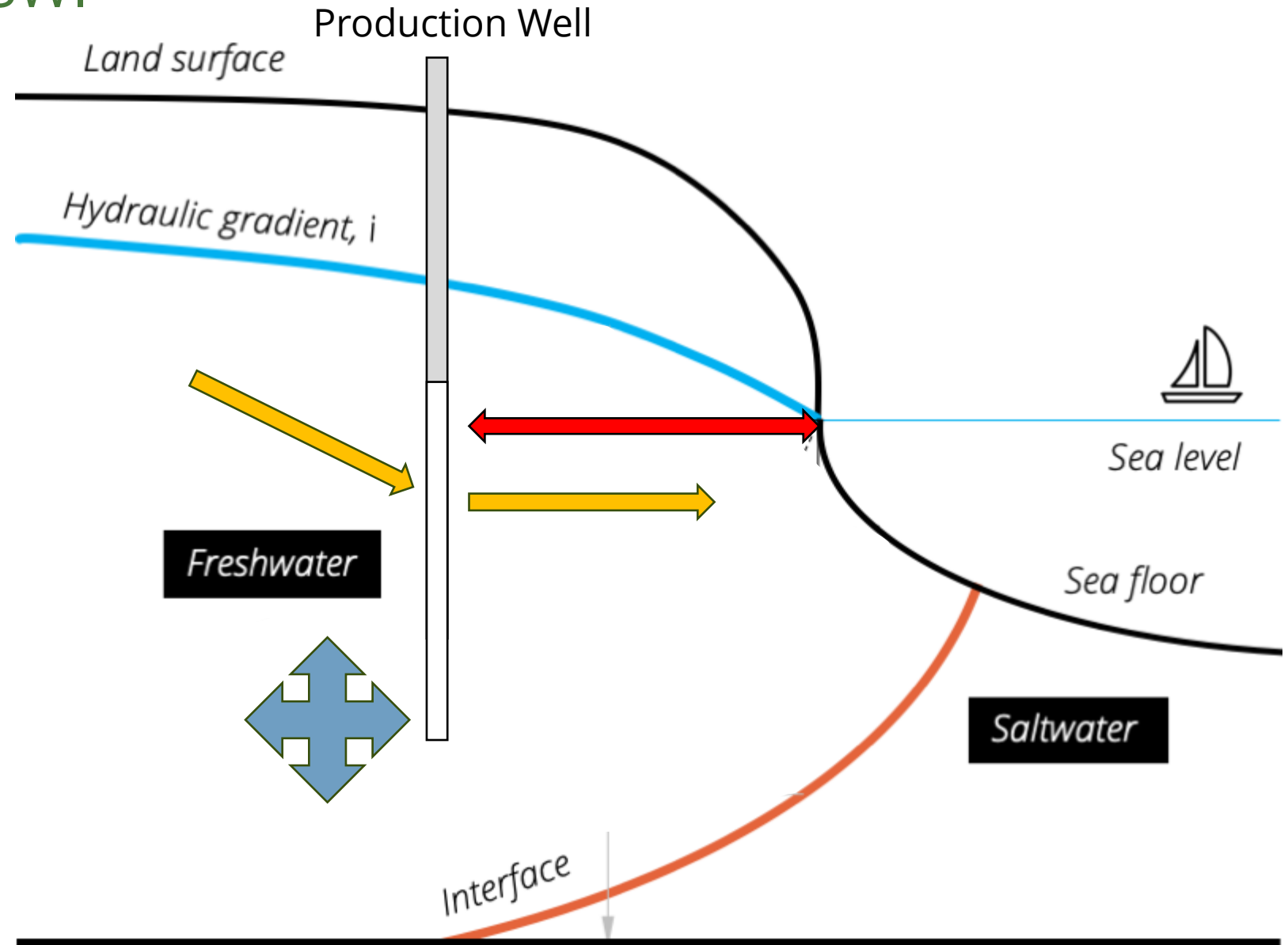
- Height of sea level
- Distance from Saltwater Source

Freshwater flux (Gradient)

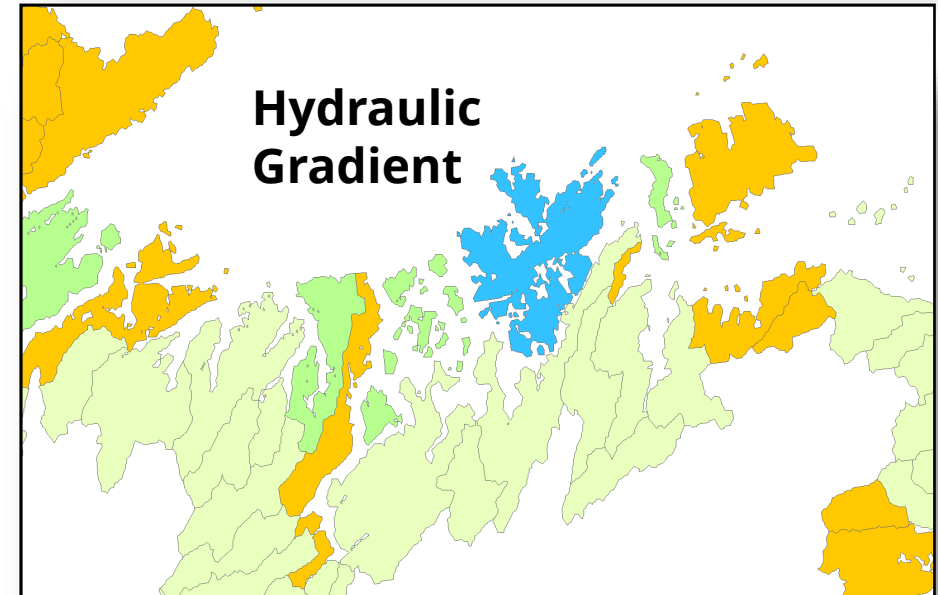
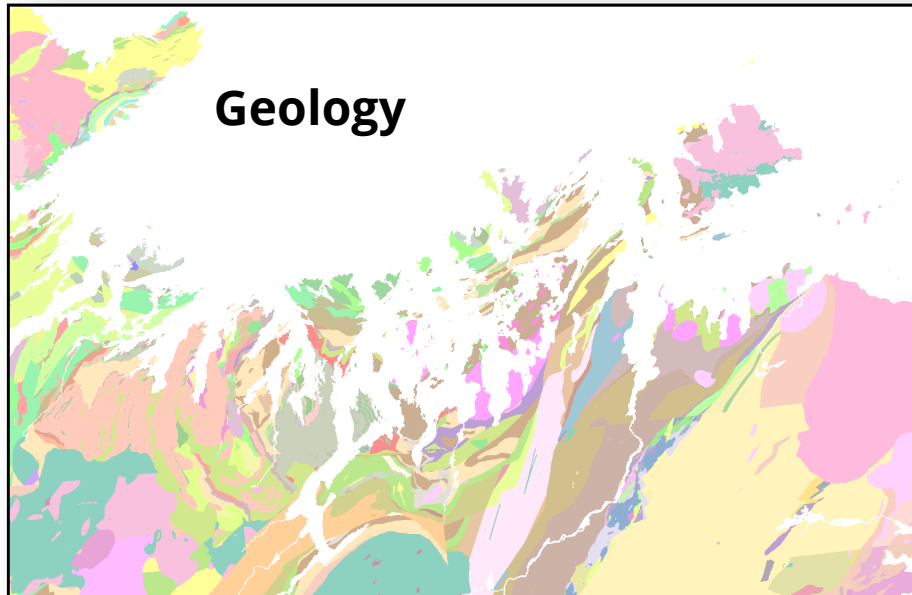
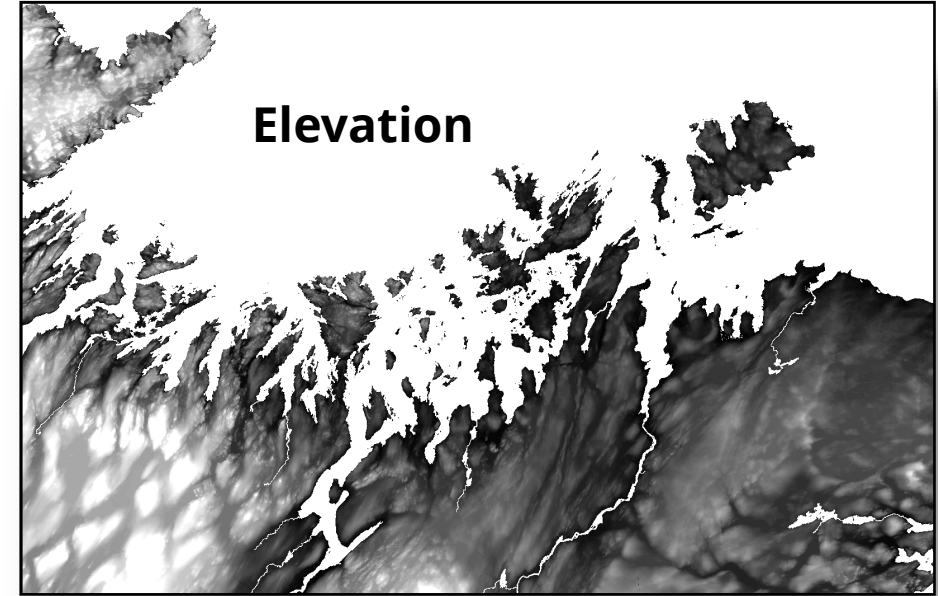
- Elevation
- Slope

Hydraulic conductivity

- Geology



Compile data that represent SWI parameters



Saltwater Intrusion Data

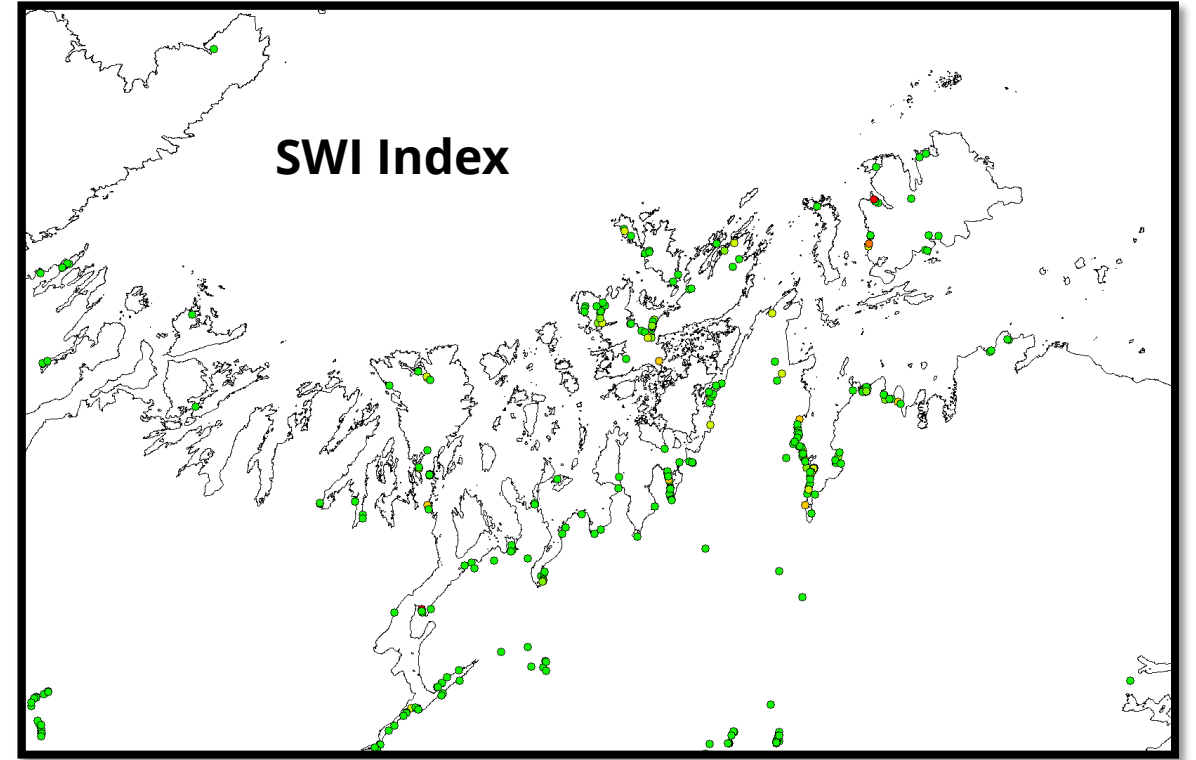
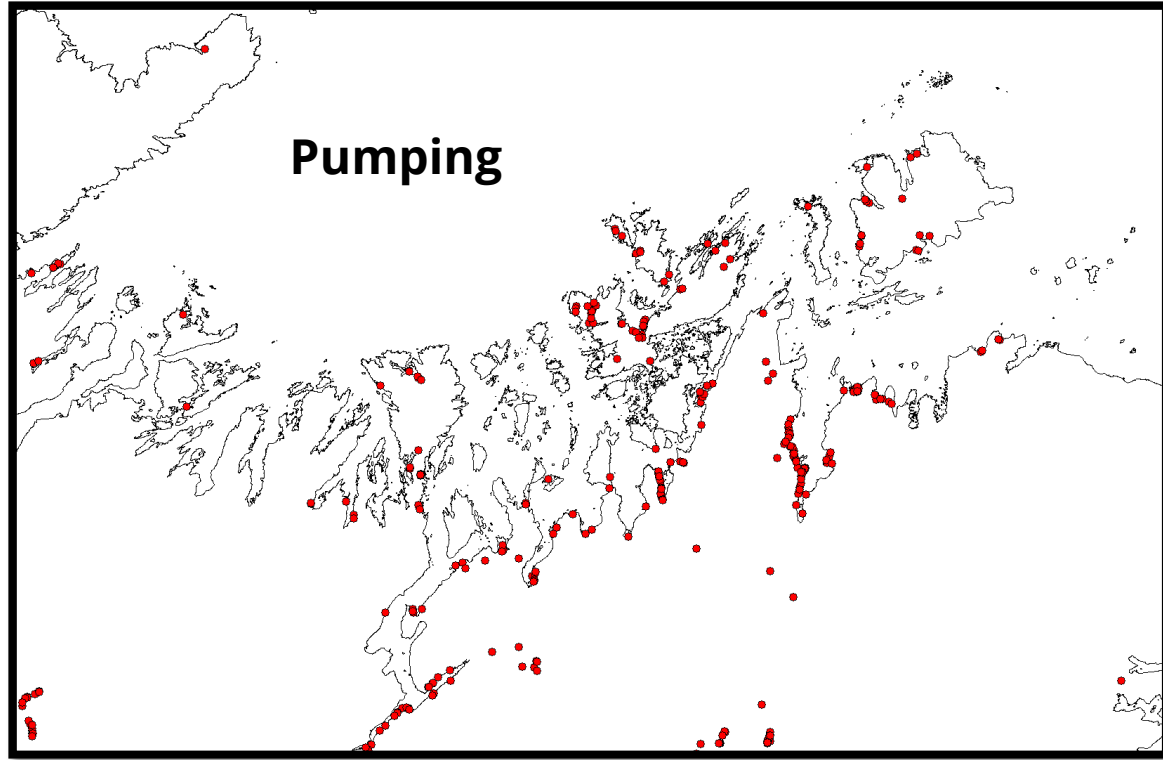
Results from provincial well water quality survey. 'SWI Index' – Sodium concentrations and ratios of major ions.

0 = No SWI

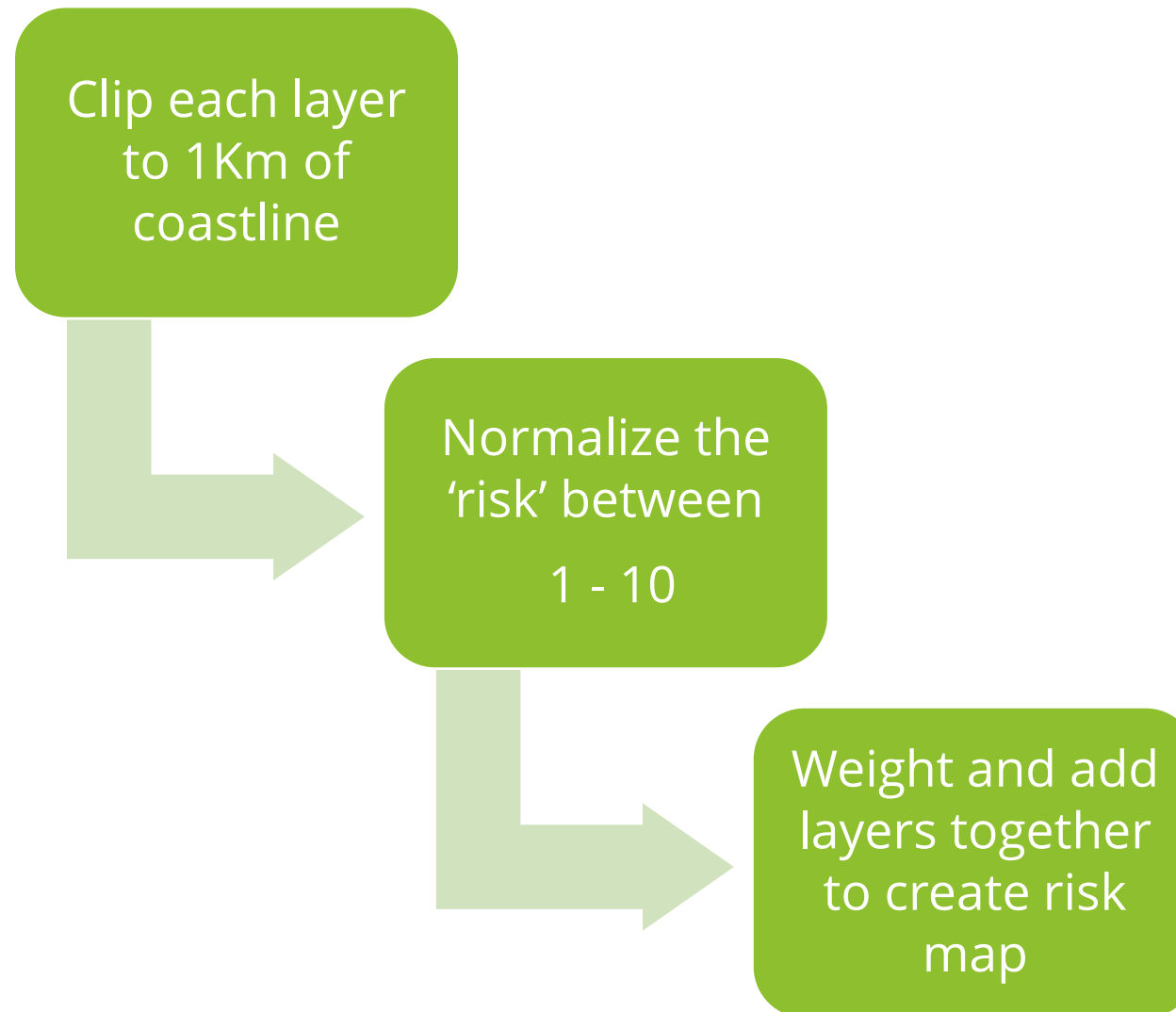
6 = likely SWI

SWI Index	Well Count	%
0	4927	94
1	30	0.6
2	49	0.9
3	129	2.5
4	70	1.3
5	2	0.04
6	8	0.2

Compile parameters that account for the influence of pumping



Index based approach to risk mapping



Summary of Parameters

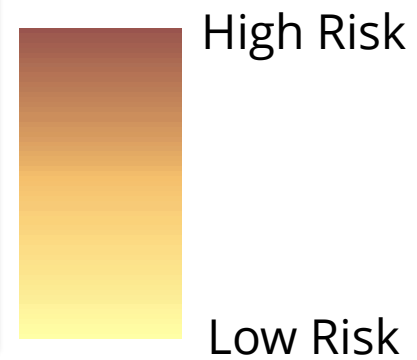
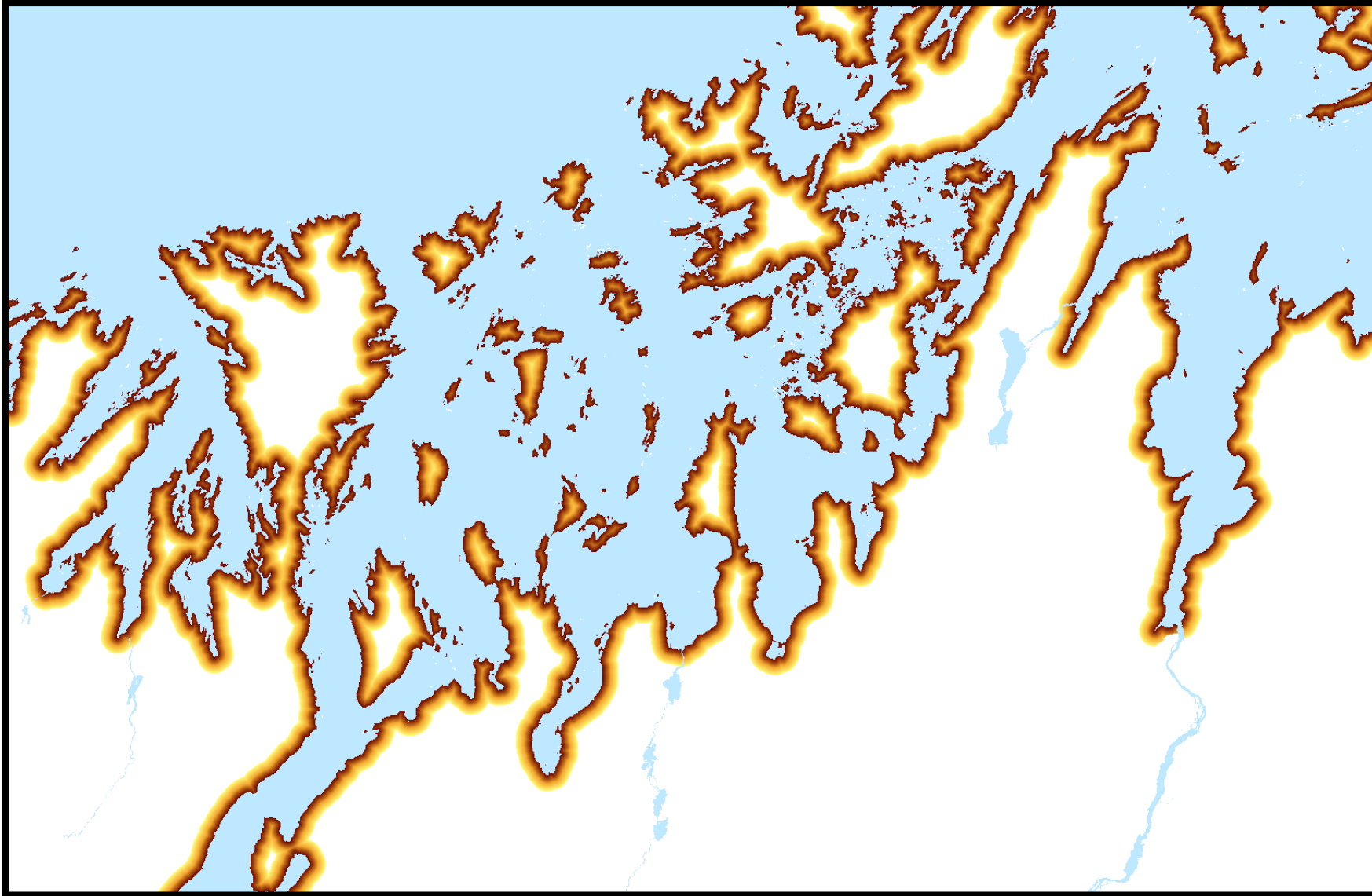
G – Gradient / regional slope ($\sim q$)
A – Bedrock / well yield index (K)
L – Topographic elevation (water table)
D – Distance to coastline (x)

Intrinsic

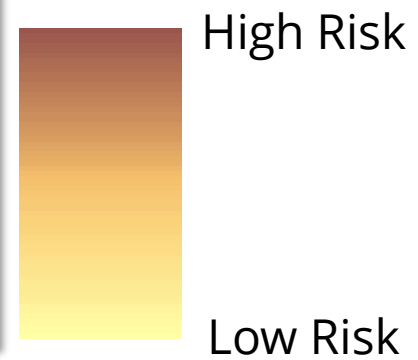
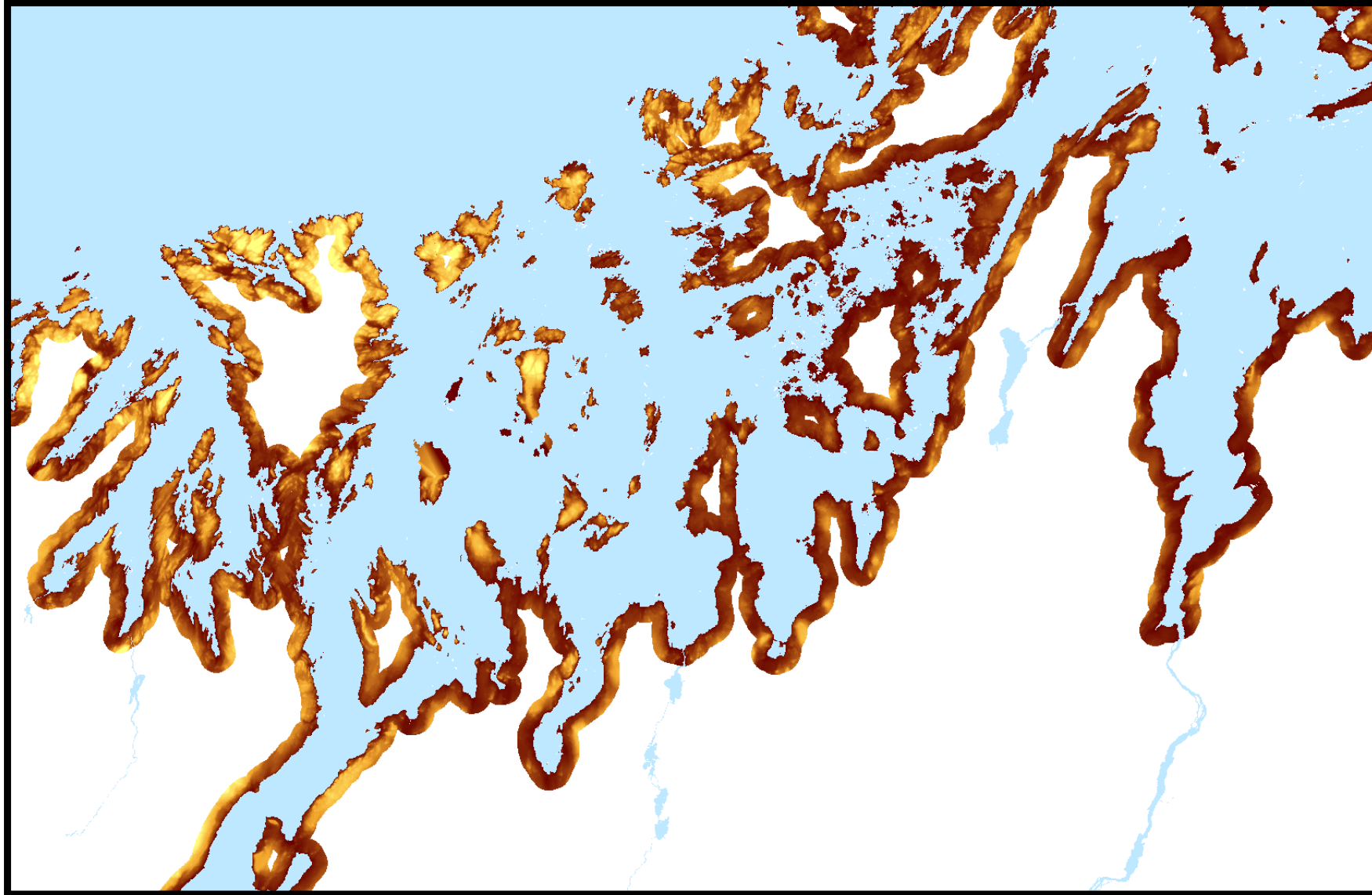
I – Impact of existing seawater intrusion
P – Pumping (well density & withdrawal volume)

Extrinsic

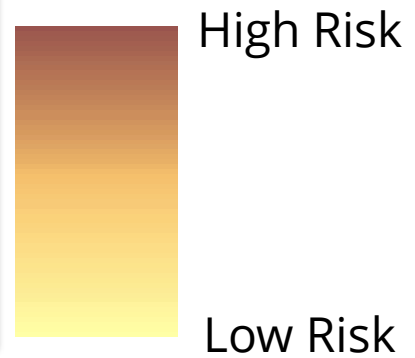
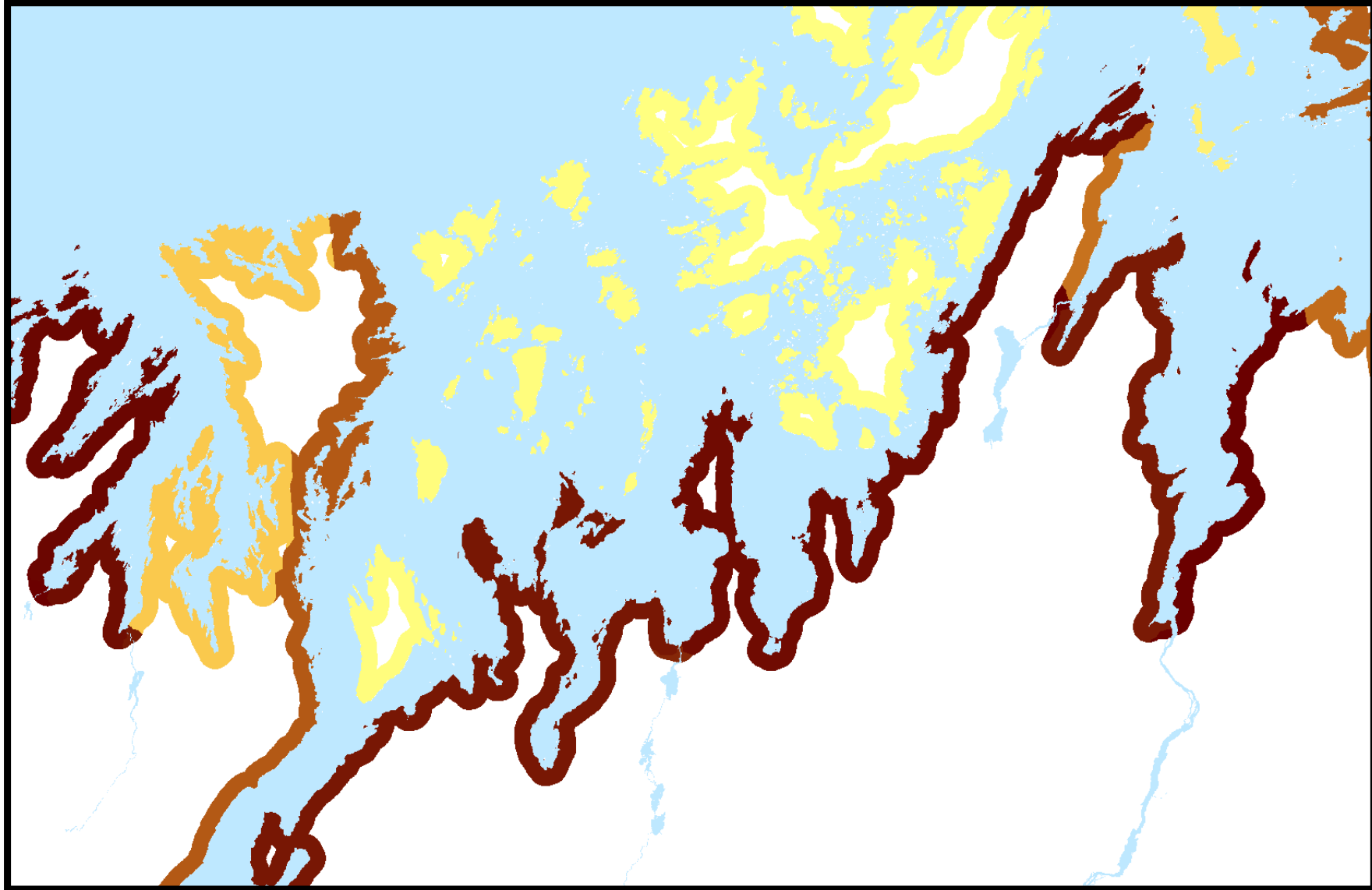
Distance



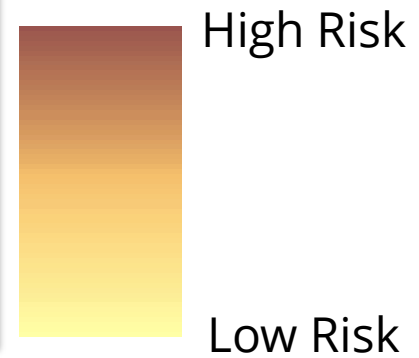
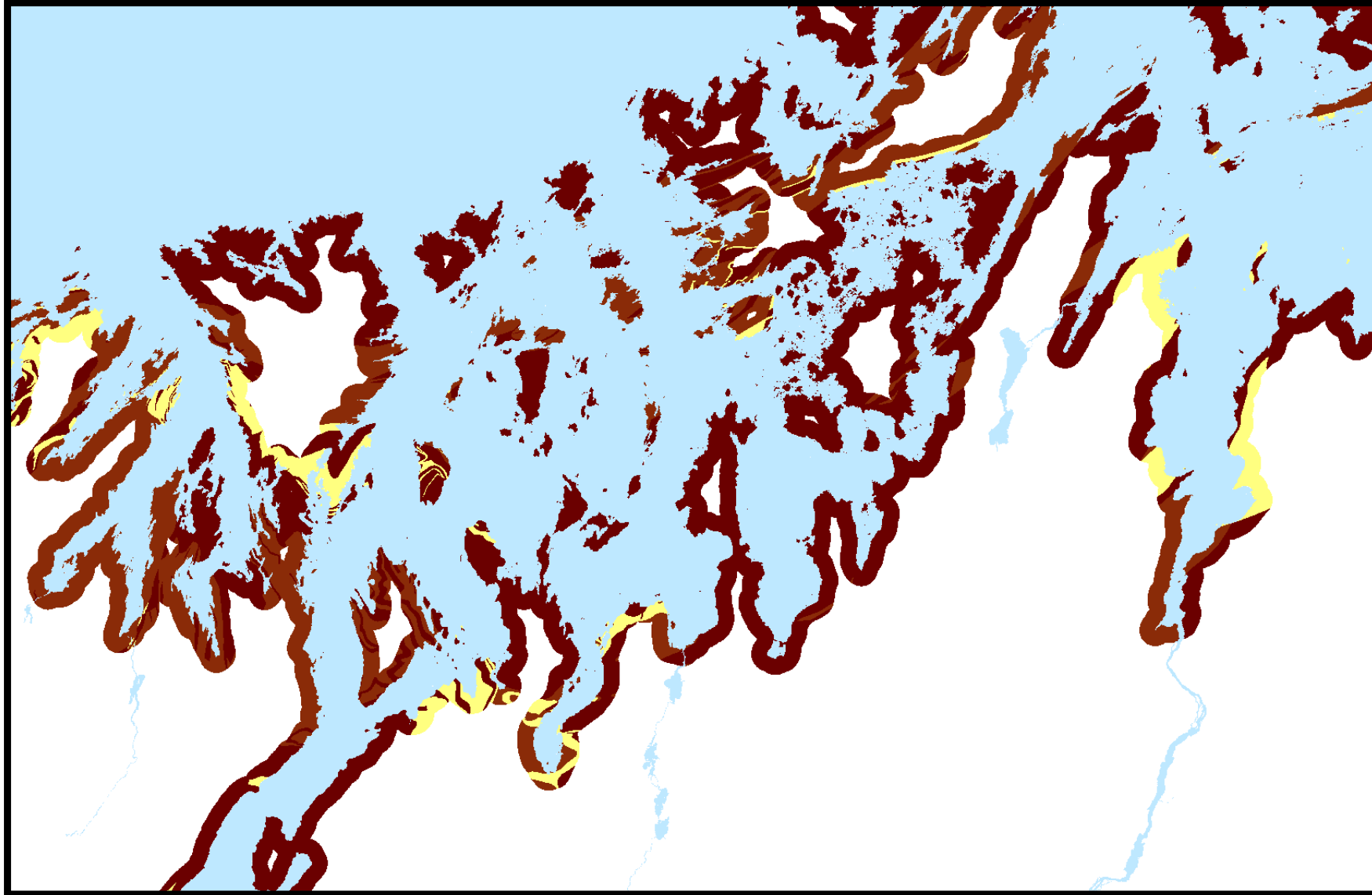
Elevation



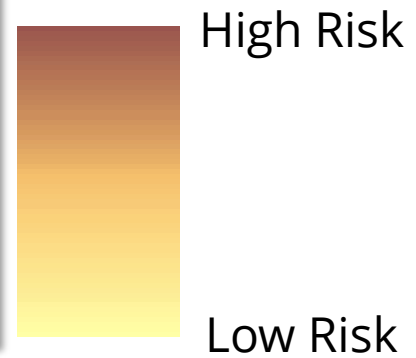
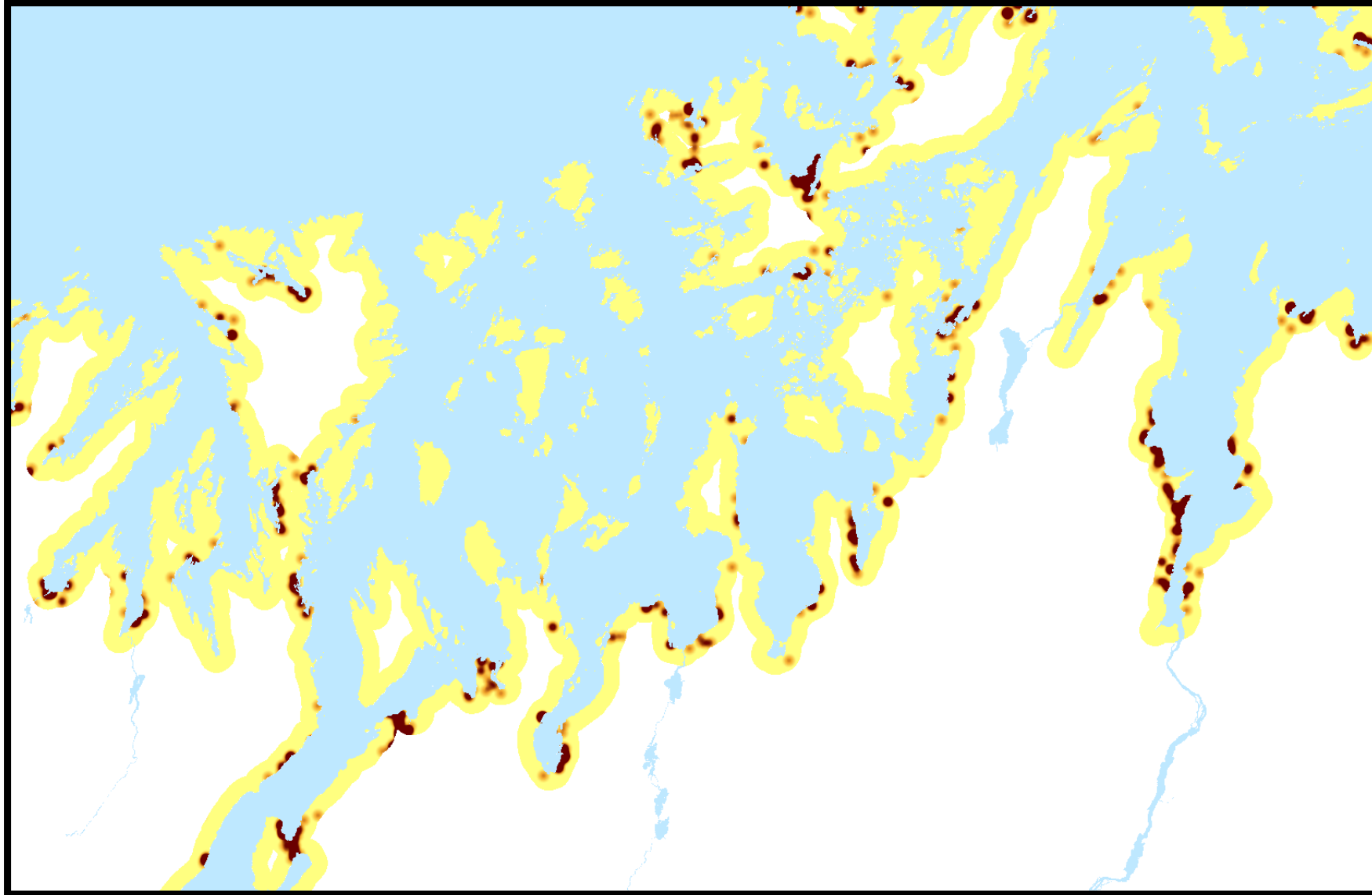
Gradient



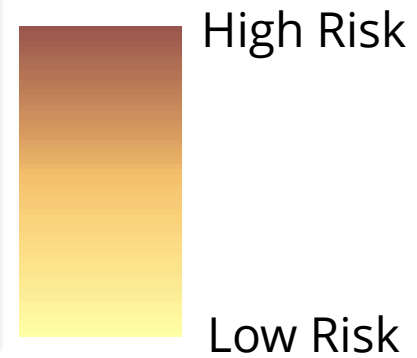
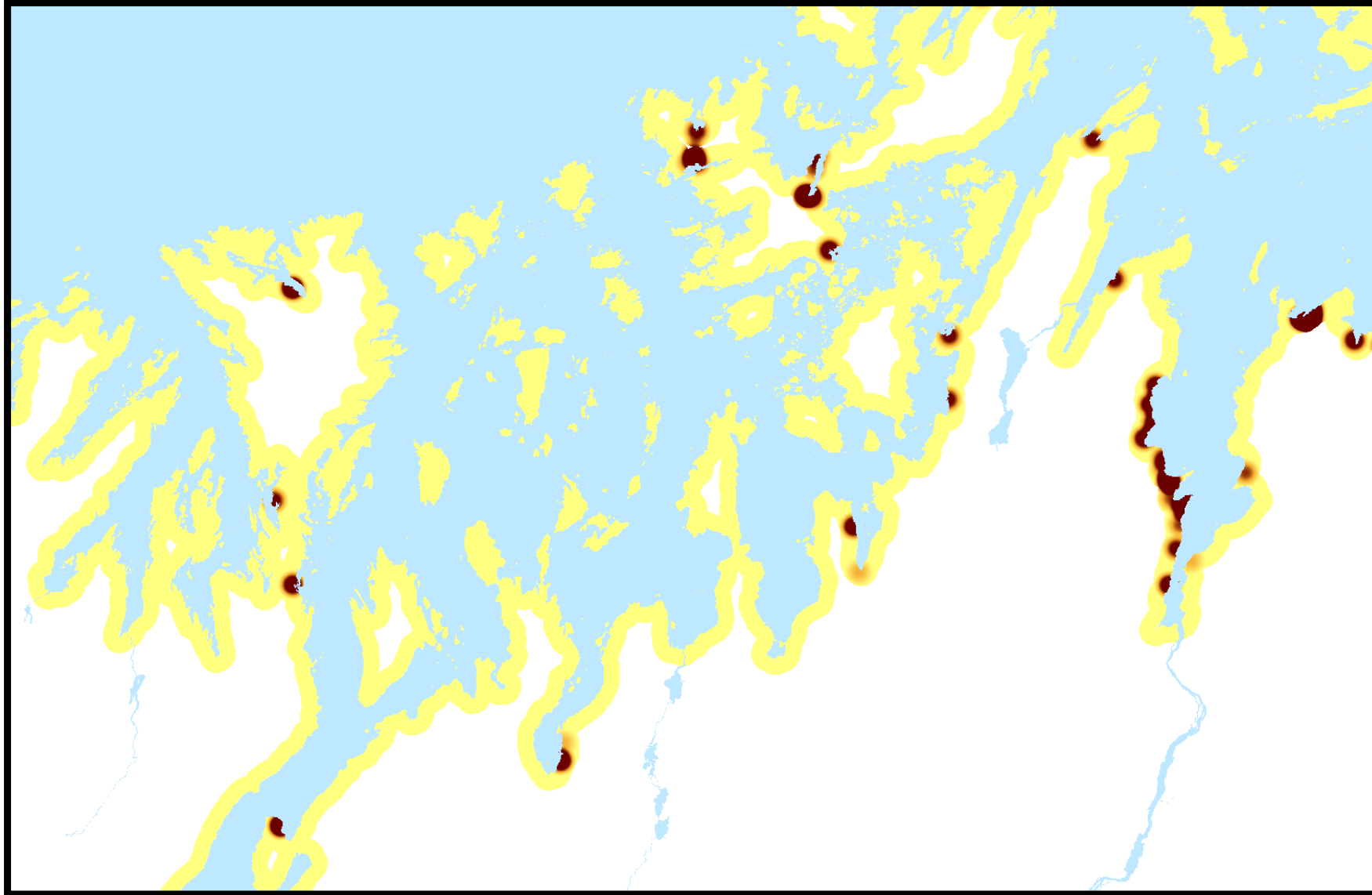
Bedrock Geology (Aquifer properties)



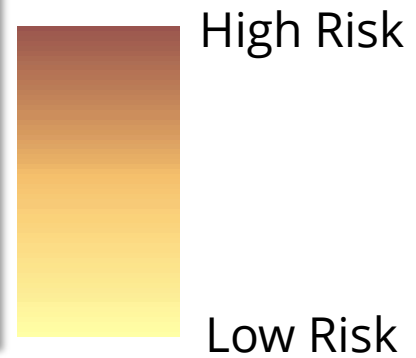
Pumping Well Density

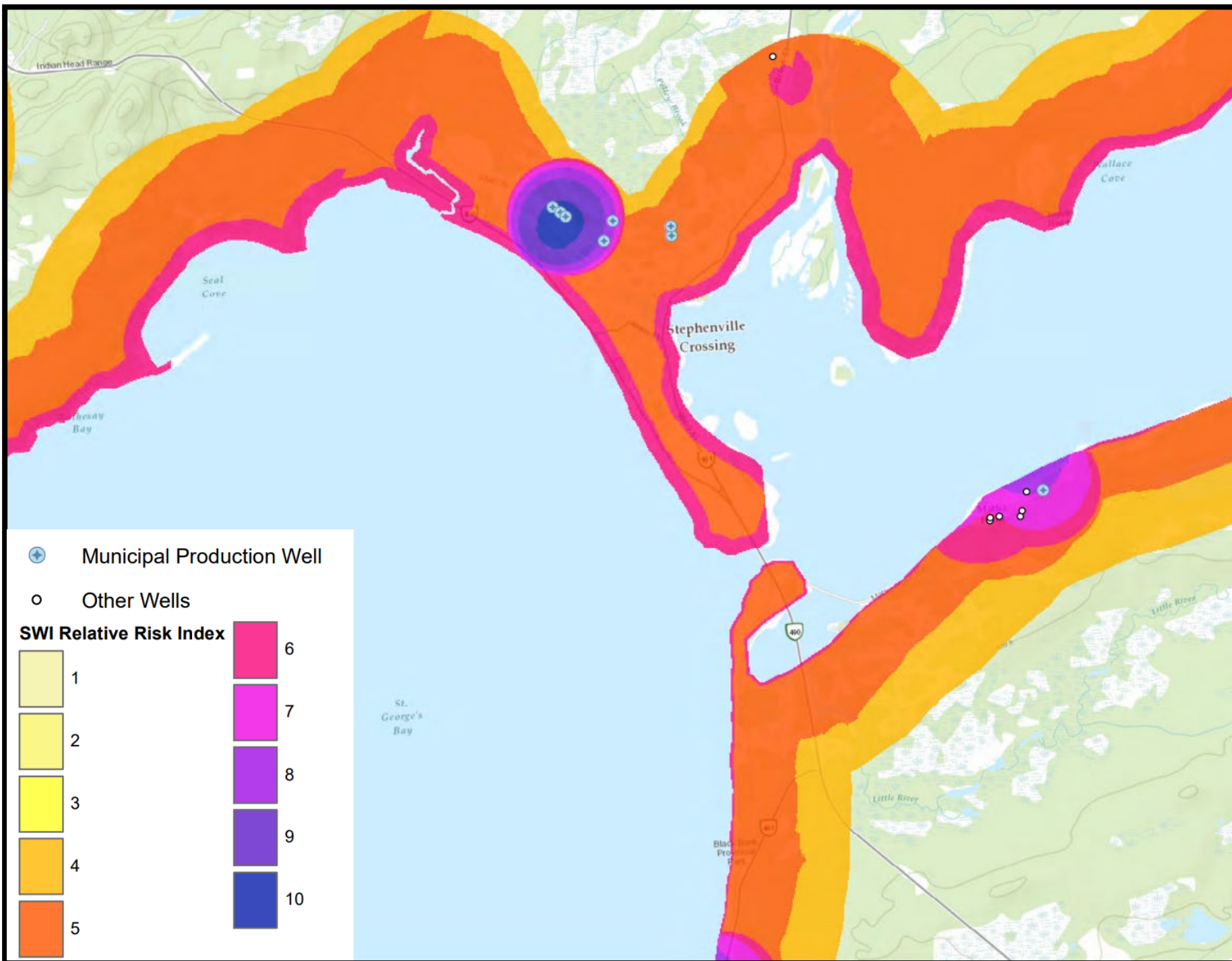


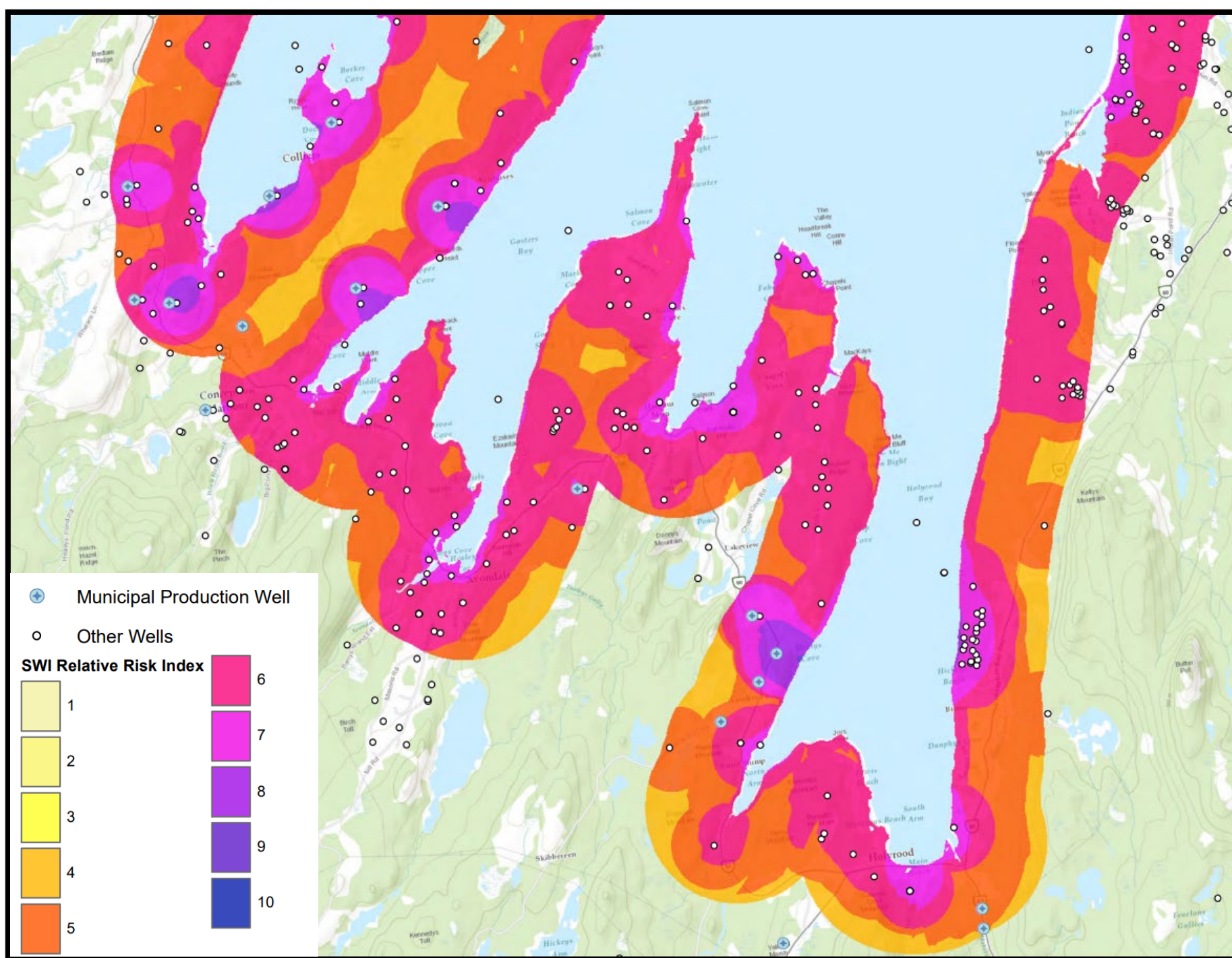
Impact of Existing SWI

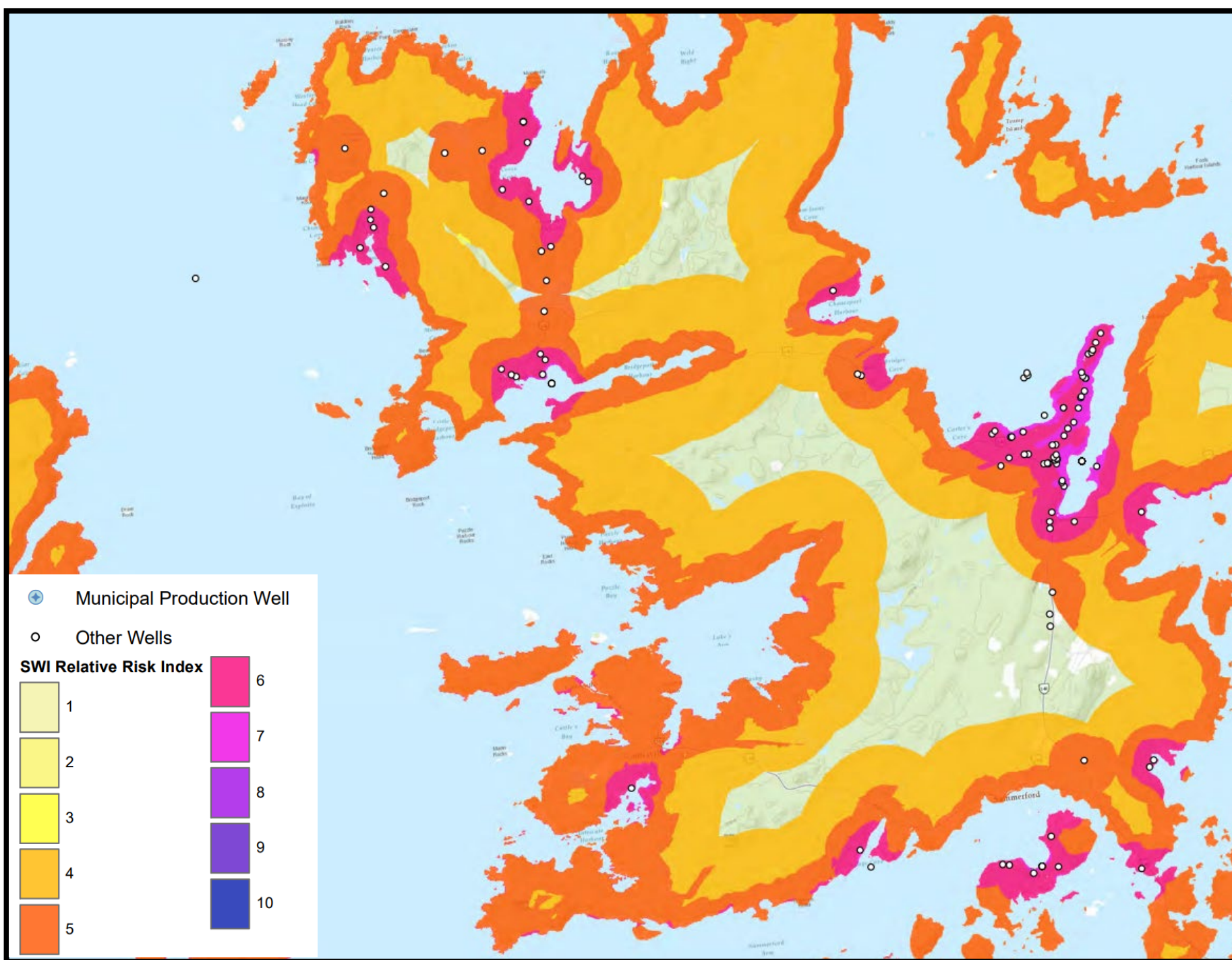


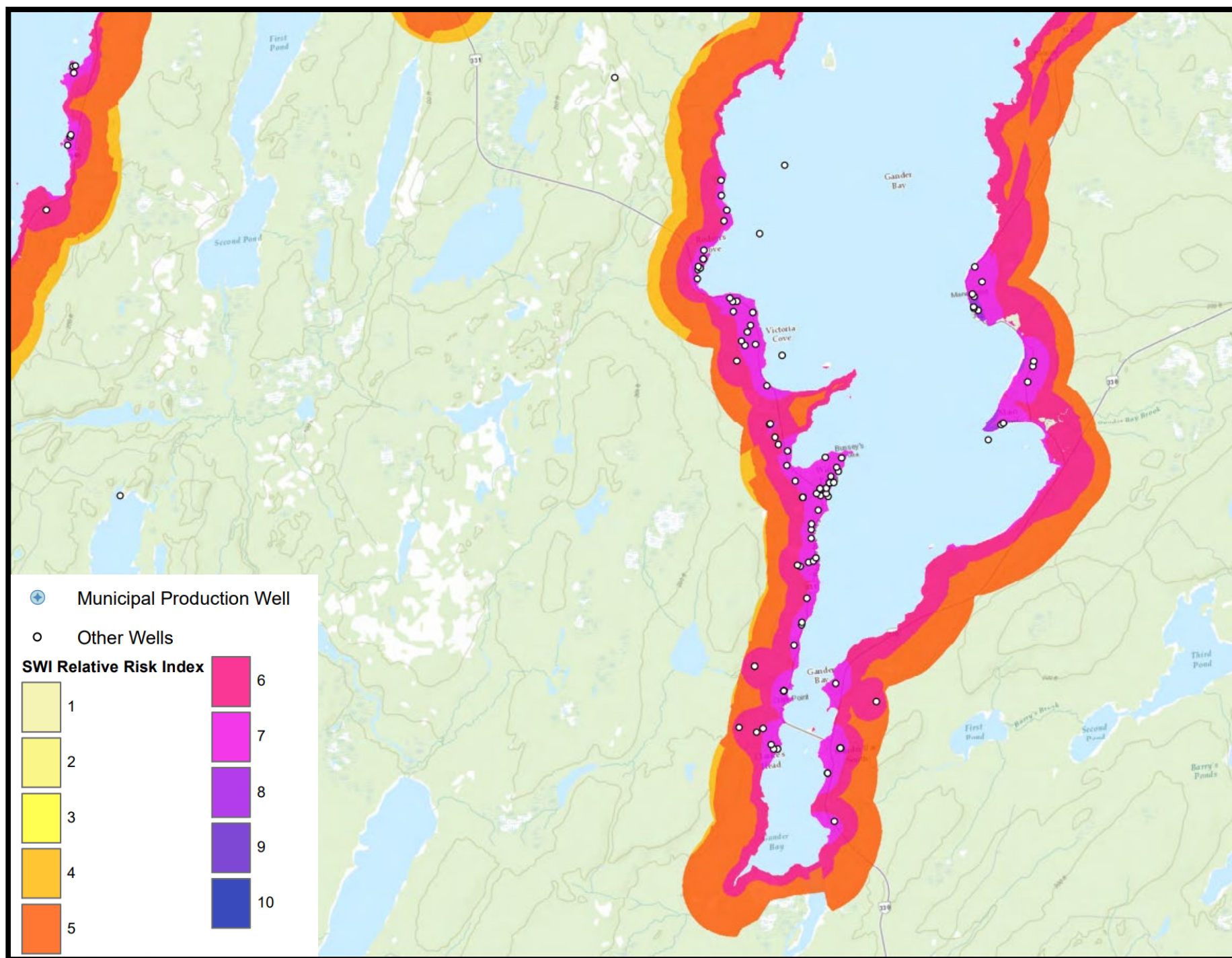
GALDIP Map











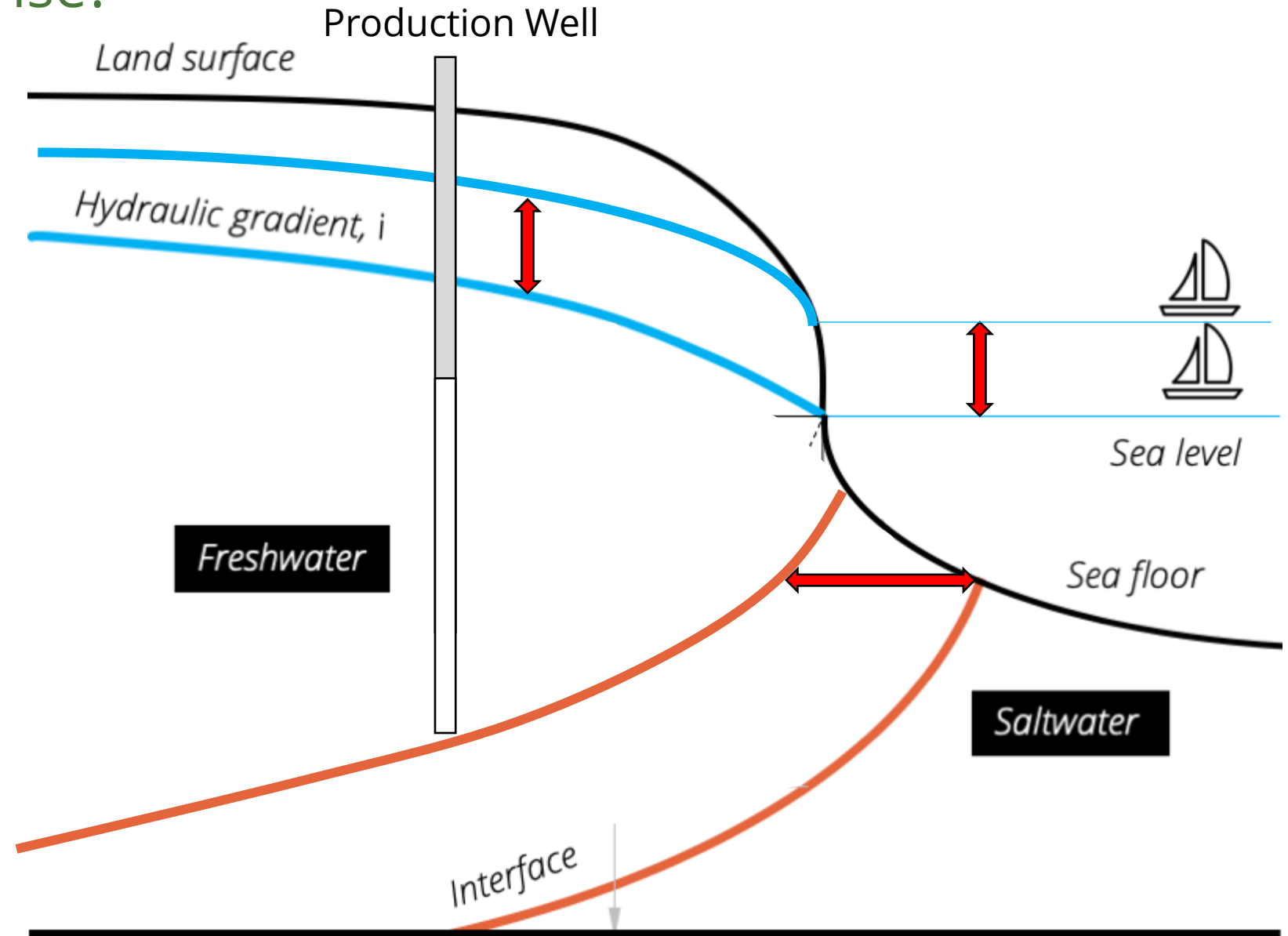
What about climate change?



What about sea level rise?

Sea Level Rise

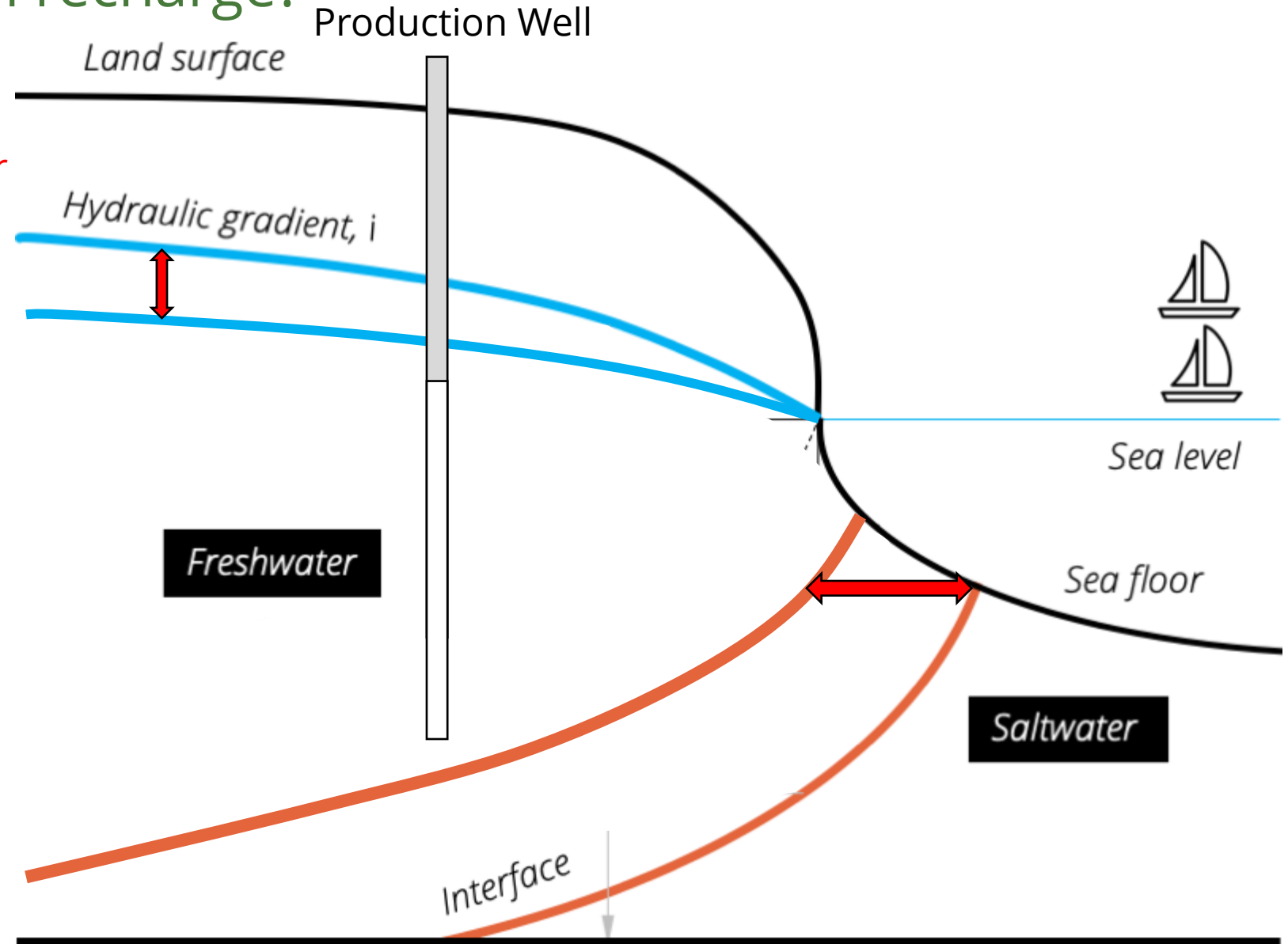
- Distance to saltwater source decreases.
- Interface moves landwards.



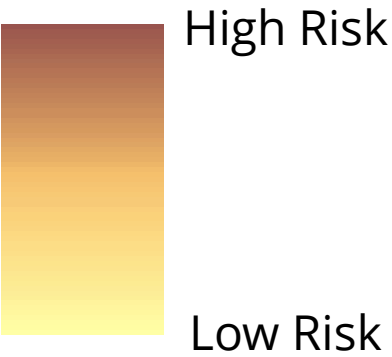
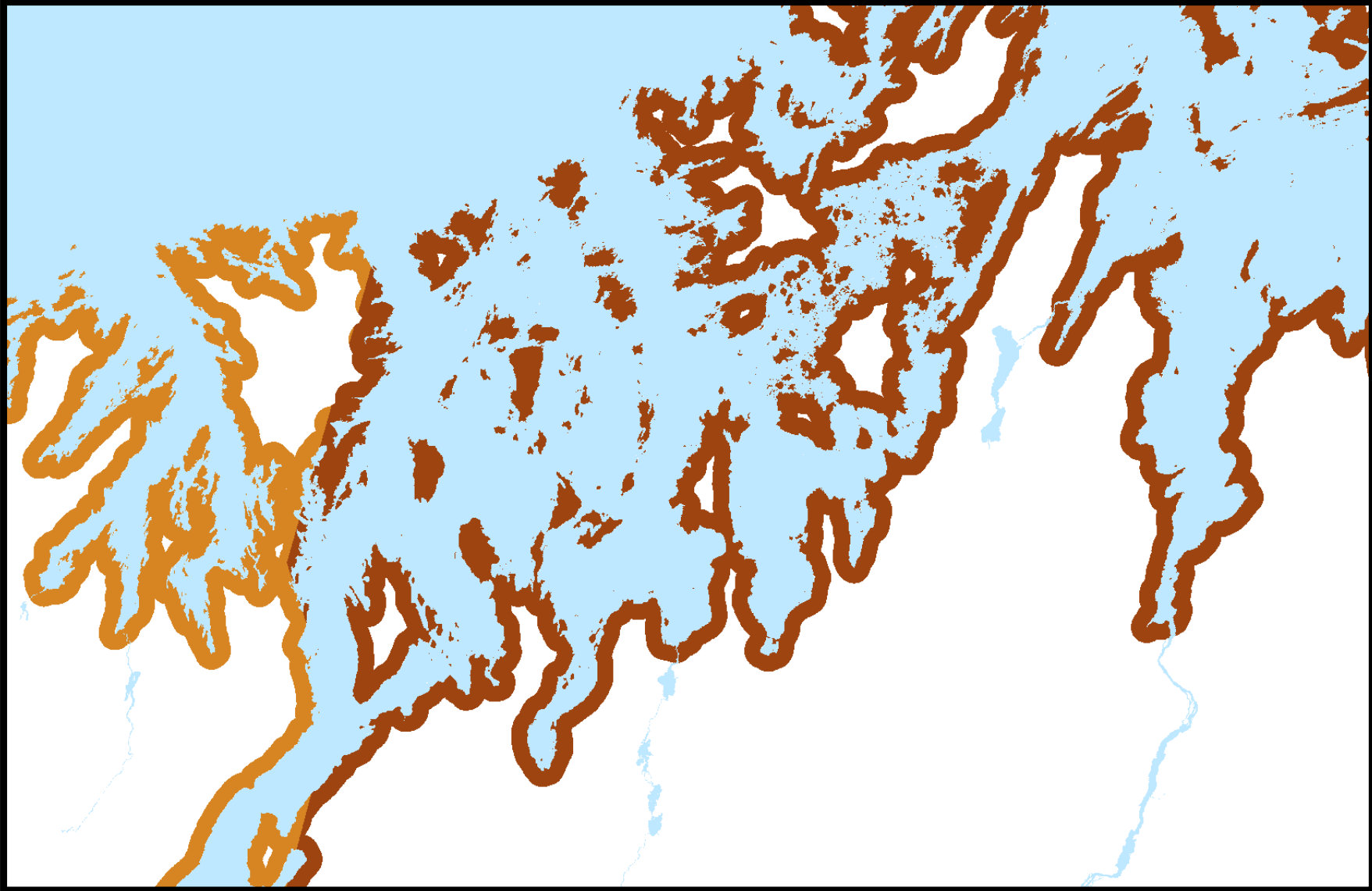
What about changes in recharge?

Changes in Recharge

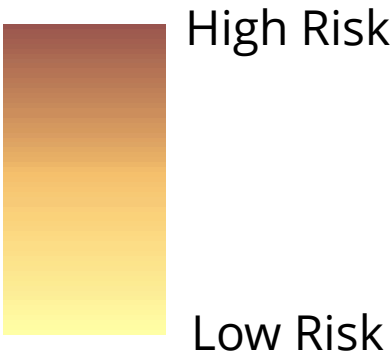
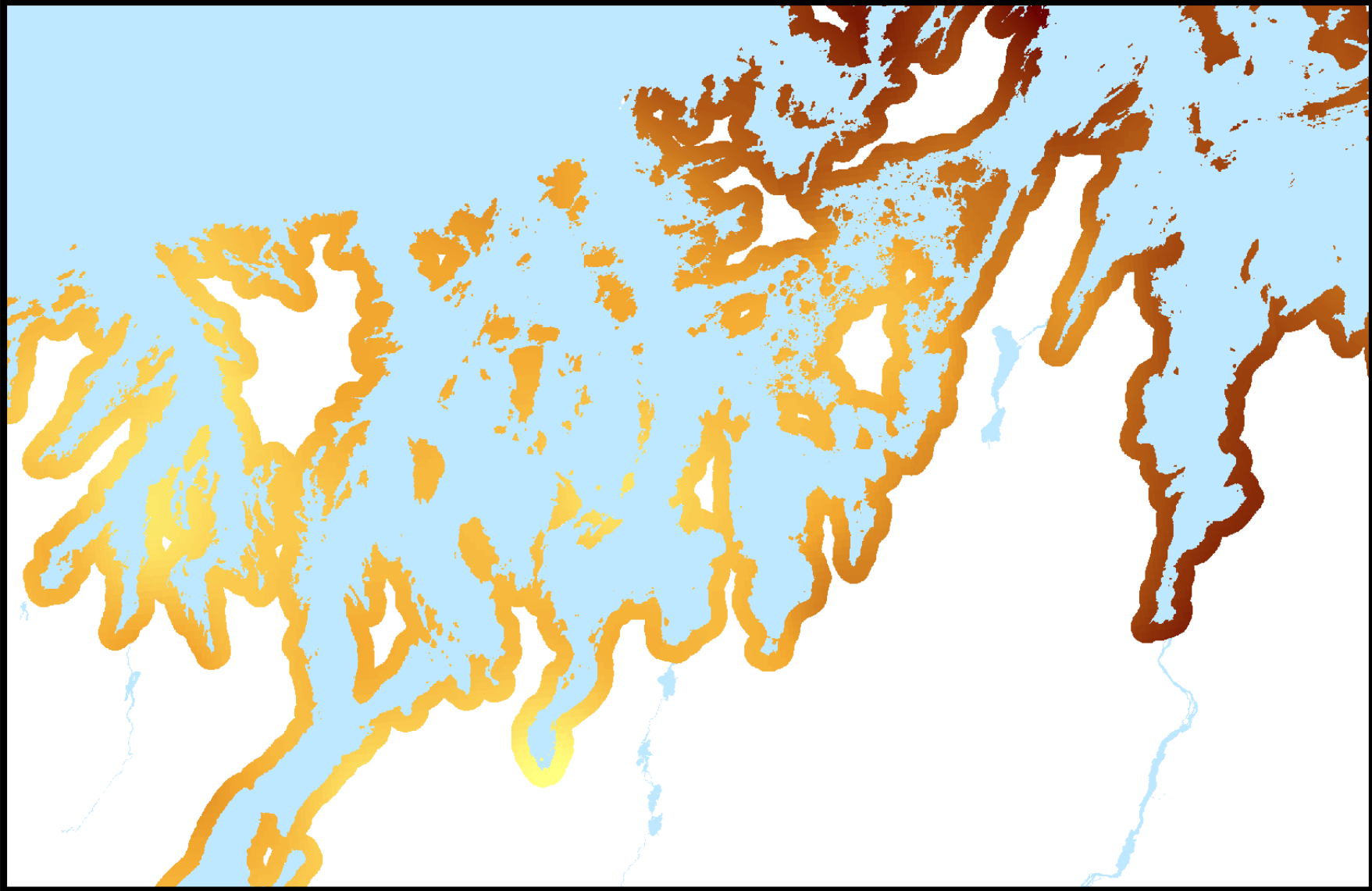
- Lower water tables as less water is recharging the aquifer
- Interface moves landwards.



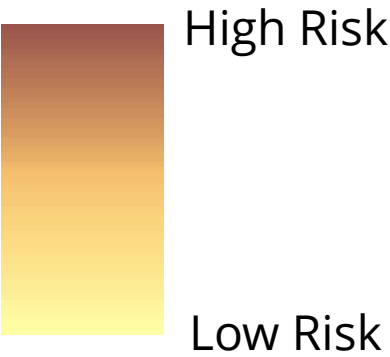
Sea Level Rise



Recharge



Climate Change Index

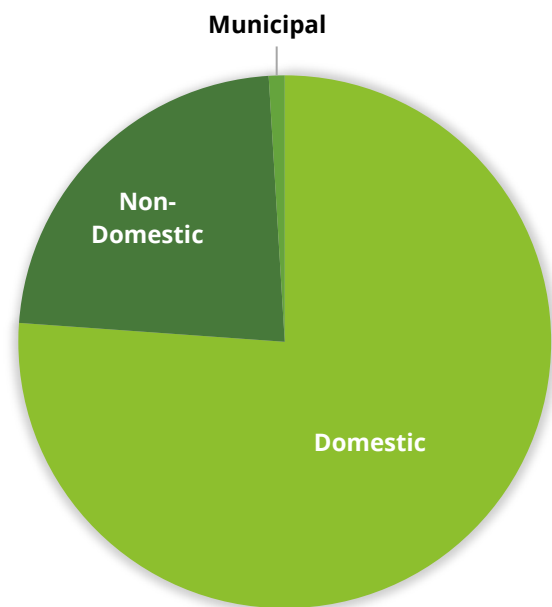


An aerial photograph of a landscape, possibly a coastal or wetland area, with a complex network of orange, wavy lines overlaid on it. These lines resemble a stylized map or a data visualization. A semi-transparent green horizontal banner is positioned across the middle of the image, containing the word "Questions" in white text.

Questions

Newfoundland and Labrador Groundwater Overview

~27,000 Records in the Well Database



	Depth to Bedrock (m)	Well Depth (m)	Static Water Level (m)	Airlift Yield (L/min)
# Records	5247	18 503	4151	16 825
Mean	5.7	57	6.1	25
Variance	48	1126	76	4352
Standard Deviation	7	34	8.7	66
Minimum	0	2.0	0	0
First Quartile	2.1	31	3.0	2.0
Median	4.0	49	5.0	9.0
Third Quartile	6.7	76	6.0	23
Maximum	110	400	304	2250

Data from CBCL 2010 Well Database Study

Table B1. Data Sources for SWI Parameters

Abbreviation	Data Target	Data Type	Data Source
G	Regional Slope / (groundwater gradient)	Watershed boundaries	HydroBASINS
		DEM & contour mapping	NL LiDAR & Topographic Data
A	Well Yield Index & Bedrock Geology Mapping (hydraulic conductivity)	Statistical analysis of driller's airlift yield estimates and well depths	Newfoundland and Labrador water well database
		Bedrock Geology Units	NL Bedrock Geology Mapping
L	Ground surface elevation (water table elevation)	Newfoundland DEM	NL LiDAR & Topographic Data
		Labrador Contours	
D	Distance to Coastline	NL Coastline	NL LiDAR & Topographic Data
I	Water quality index / indicator parameters (existing impacts)	Municipal & private well water sampling data	NL Water Resources Division
P	Density of production wells & pumping rates	Locations & types of wells	Newfoundland and Labrador water well database; municipal & public water system records
S	Projected Sea Level Rise	Sea Level Rise Projections for 2100	Geological Survey of Canada
R	Changes to groundwater recharge rate	Precipitation & dry spell indexes	Government of Canada; Pacific Climate Impacts Consortium

Table B2. Summary of Data Ranges and Indexing Methods

Abbreviation	Quantity	Minimum	Maximum	Low Risk	High Risk	Data Transformation	Rescaled to Index Range	Subtotal Weightings		Final Weightings	
G	Regional slope by coastal watershed (m/m)	0.004	0.877	Steepest regional slope	Shallowest regional slope	logarithmic	1-10	Intrinsic Index	0.3	SWI Index	0.425
A	Well Yield Index, statistically grouped by bedrock geology mapping	0.77	1.27	Highest Inferred K	Lowest Inferred K	index is log-scaled	1-10		0.1		
L	Surface Elevation (masl)	-15	1159	Greatest elevation	Lowest elevation	square root	1-10		0.3		
D	Distance to Coastline (m)	0	1000	Greatest distance from coast	Smallest distance from coast	square root	1-10		0.3		
I	Water Quality Index, seawater indicators & ratios	0	6	Lowest number of SWI indicators	Highest number of SWI indicators	indexed and summed, distance-density kernel	1-10	n/a	n/a	SWI Index	0.425
P	Well distance & pumping rates	0	14200	Lowest Pumping Density	Highest Pumping Density	distance-density kernel; power	1-10		n/a		0.15
S	Sea Level Rise Projections	0	1.4	Lowest sea-level rise	Greatest sea-level rise	linear	1-10		n/a		0.5
R	Total Precipitation (% change)	10.3	26.5	Larger increase in precipitation	Smaller increase in precipitation	linear; per original indexing methods	1-10	Recharge Index	0.25	Climate Change Index	0.5
	Simple Precipitation Intensity Index (% change)	9.4	16.9	Smaller increase in intensity	Larger increase in intensity		1-10		0.25		
	Maximum Length of Dry Spell (% change)	-21	5	Smaller increase in dry spell	Larger increase in dry spell		1-10		0.25		
	Warm Spell Duration Index (relative increase in days)	56	214	Smaller increase in warm spell	Larger increase in warm spell		1-10		0.25		

Parameter	Range for Index = 1	Range for Index = 2
Sodium Concentration (mg/L)	100-200	>200
Selenium Concentration (mg/L)	0.002-0.004	>0.004
SAR	1-2	>2

SAR = Sodium Adsorption Ratio = $[\text{Na}^+] / \sqrt{([\text{Ca}^{2+}] + [\text{Mg}^{2+}])}$ me/L